NOTES ON METEORITES.[1]

III.

IDENTITY OF ORIGIN OF METEORITES, LUMINOUS METEORS, AND FALLING STARS.

It is very fortunate for science that many of the meteorites so carefully preserved in our museums *have been seen to fall.* This being so we possess full accounts of the accompanying phenomena and effects.

These comprise the most vivid luminosity; visible and audible explosions, in some cases heard over thousands of square miles of country, and at times a long train in the sky indicating the meteor path, which sometimes remains visible for hours.

Now precisely similar effects have been noted when nothing has reached the earth's surface; and in the thousands of records of the phenomena presented by luminous meteors, fire-balls, bolides, or shooting or falling stars as they have been variously called, we have the links which connect in the most complete manner the falls of actual irons and stones from heaven with the tiniest trail of a shooting or falling star, *une étoile qui file, qui file, et disparait.*

The heavy masses fall by virtue of their substance resisting the friction of the air, the grains are at once burnt up and fill the upper regions of the earth's atmosphere with meteoric dust.

As we have seen, the weights of meteorites which have actually fallen vary between many tons and a few ounces, the latter being, in all probability, fragments shattered by the explosion. In the case of some shooting-stars, the actual weight involved has been estimated by Prof. Herschel as low as *two grains,* not one out of twenty estimated by him exceeding a pound.

It may appear impossible that such atoms should produce the brilliant effects observed, but Prof. Herschel has calculated that a single grain moving at the rate of 30 miles a second represents a dynamical energy of 55,675 foot-pounds. This energy is converted by the resistance of our grosser air into heat, as the motion of a projectile is converted into heat by its impact on the target;[2] and hence the combustion of the matter of the meteorite, and perhaps even the incandescence of the air through which it rushes with such lightning velocity. This luminosity commences often at a height of 80 miles, and sometimes even higher, in regions where the atmosphere must be excessively rare.

Could these little bodies pierce our envelope as readily as do their larger cousins, the meteoric stones and meteoric irons, we should certainly have the advantage of placing them in our museums; but, on the other hand, the bombardment—the *feu de ciel*—might be one to which the *feu-d'enfer* of all terrestrial artillery would be, in the gross total of results, as mere child's play.

But the identity of such phenomena as these is by no means the only line of evidence demonstrating the connection now in question.

Proof from the Chemistry of Fire-balls.

The spectral appearances observed with meteors, fire-balls, and shooting-stars, which explode and produce luminous effects, are entirely in harmony with those observations on the spectra of meteorites to which I have referred.

The observations, so far as they have gone, have given decided indications of magnesium, sodium, lithium, potassium, and of the carbon flutings seen in comets.

Prof. Herschel and Herr Konkoly have both noticed that in the generality of cases the lines of magnesium (one of the constituents of the olivine) show themselves first in the ordinary meteor or falling star, and the beautiful green light which is so often associated with these falling bodies is due to the incandescence of the vapour of magnesium.

The following quotations from Konkoly and Prof. Herschel are among the authorities which may be cited for the above statement:—

"On August 12, 13, and 14 I observed a number of meteors with the spectroscope; amongst others, on the 12th, a yellow fire-ball with a fine train, which came directly from the Perseid radiant. In the head of this meteor the lines of lithium were clearly seen by the side of the sodium line. On August 13, at 10h. 46m. 10s., I observed in the north-east a magnificent fire-ball of emerald-green colour, as bright as Jupiter, with a very slow motion. The nucleus at the first moment only showed a very bright continuous spectrum with the sodium line; but a second after I perceived the magnesium line, and I think I am not mistaken in saying those of copper also. Besides that, the spectrum showed two very faint red lines."[1]

"A few of the green 'Leonid' streaks were noticed in November (1886) to be, to all appearances, monochromatic, or quite undispersed by vision through the refracting prisms; from which we may at least very probably infer (by later discoveries with the meteor-spectroscope) that the prominent green line of magnesium forms the principal constituent element of their greenish light."[2]

Again, later on in the same letter, Prof. Herschel mentions Konkoly's observation of the bright *b* line of magnesium, in addition to the yellow sodium line, in a meteor on July 26, 1873. I again quote from Prof. Herschel:—

"On the morning of October 13 in the same year, Herr von Konkoly again observed with Browning's meteor-spectroscope the long-enduring streak of a large fire-ball, which was visible to the north-east of O'Gyalla. It exhibited the yellow sodium line and the green line of magnesium very finely, besides other spectral lines in the red and green. Examining these latter lines closely with a star spectroscope attached to an equatorial telescope, Herr von Konkoly succeeded in identifying them by direct comparison with the lines in an electric Geissler-tube of marsh-gas. They were visible in the star-spectroscope for eleven minutes, after which the sodium and magnesium lines still continued to be very brightly observable through the meteor-spectroscope."[3]

Another series of observations gives continuous spectra for the nucleus, and two trains with sodium, and a third with sodium and a predominant green band, which was doubtless *b* of magnesium, the meteor itself being of emerald-green colour.

In cases where the temperature has been higher, the bright line spectrum of iron has been associated with the bright lines of magnesium in the spectrum of the falling star, so that the two substances which are among the chief constituents of stones and irons—precisely the two substances which we should expect to find—are actually those which have been observed.

The two lines which Konkoly supposes are probably due to copper will, I expect, be found to be iron lines when other observations are made of the spectra of meteors.

These spectral appearances are naturally associated with colours, and again we find that the colours of the trail, when meteorites have fallen, closely resemble those observed when no fall has been observed.

Green is a tolerably common colour, especially in slow-moving fire-balls about equal to Venus in lustre. These generally leave a short trail of red sparks.

About 10 per cent. of all shooting-stars show a distinct colour, the most usual being orange or red, the slowly-moving ones generally being red. The larger ones, or those with the longest trails, often turn from orange to bluish white, like burning magnesium. Sometimes the change is very sudden and startling.[5]

A purple or mauve tint, like that given by copper, is sometimes seen.

Proof from the Aurora.

When we come to consider the number of meteorites which fall upon the earth daily we shall find that it is enormous; and this being so, if we can trace this dust in the air, or after it has fallen, or both, if chemical examination shows it to be identical with that of meteorites, we shall be supplied with another argument which can be used in support of the fact that the bodies which produce the dust are meteoric in their origin.

One must suppose that these meteors in their passage through the air break into numerous fragments, that incandescent particles of their constituents, including nickel, iron, manganese, and the various silicates of iron, are thrown off, and that these or the products of their combustion eventually fall to the surface as almost impalpable dust, among which must be magnetic oxide of iron more or less completely fused. The luminous trains of falling stars are probably due to the combustion of these innumerable particles, resembling the sparks which fly from a ribbon of iron burnt in oxygen, or the particles of the same metal thrown off when striking a flint. It is known that such particles in burning take a spherical form, and are surrounded by a layer of black magnetic oxide.

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[1] Continued from p. 458.

[2] The particles of iron in a large projectile, after impact, which is accompanied by a flash of light, are usually brought to a dark blue colour, which would correspond to about 555° F., but the momentary heat imparted is certainly greater than this.

[1] Konkoly, *Observatory*, vol. iii. 157.

[2] Herschel, letter to NATURE, vol. xxiv. p. 507.

[3] *Ibid.* See also *Astr. Nach.*, No. 2014.

[4] *Monthly Notices*, vol. xxxiii. p 575.

[5] Corder, *Monthly Notices*, vol. xl. p. 133.

How are we to trace this dust in the air? It is well known that at times the air is electrically illuminated, not only by the flashes of lightning which pass along its lower levels, but by so-called "auroral" displays in its higher reaches.

It is now many years since the idea was first thrown out that the aurora was in some way connected with shoooting-stars.

M. Zenger has prepared a catalogue of auroræ observed from 1800 to 1877, in which he shows an apparent connection between the brightest displays and the appearance of large numbers of shooting-stars.

M. Denza noted the same connection on November 27, 1872, and remarked that he had noticed it before.

Admiral Wrangel, as quoted by Humboldt, observed that in the auroras so constantly seen on the Siberian coast, the passage of a meteor never failed to extend the luminosity to parts of the sky previously dark.[1]

It is clear that in such a case as this the spectroscope is the only chemical aid applicable, and it has long been recognized that the spectrum observed is *not* the spectrum of the constituents of the atmosphere, as we can study it in our laboratories.

The spectrum, however, strictly resembles that seen in the "glows," to which reference has been made; if the factors present in both cases are meteor dust, low pressure, and feeble electric currents, the resulting phenomena should not be dissimilar.

The results of recent inquiries certainly justify us, therefore, in concluding that the upper reaches of the atmosphere contain particles giving us the spectra of magnesium, manganese, iron and carbon.

The natural origin is the dust of those bodies which are continually entering those regions, and hence the proof afforded by the spectroscopic observation of shooting-stars, that they are identical in chemical composition with meteorites, is strengthened by these auroral observations, while, on the other hand, the origin of the auroral spectrum is placed beyond all doubt.

Proof from the Fallen Dust.

It is universally recognized that the atmosphere holds in suspension an immense number of very minute particles of organic and inorganic origin. These must be either dust taken up by aërial currents from the ground—the result of volcanic action—or extra-terrestrial bodies. Many scientific men, among whom we may mention Ehrenberg, Daubrée, Reichenbach, Nordenskjöld, Tissandier, Murray, and Renard, have studied this problem. Dust collected in various places at different times has been examined with a view of determining whether its origin was meteoric. In many cases, in which chiefly definite iron chondroi have been observed, the evidence has seemed very strong in favour of the view.

It is at once obvious that the detection of such dust which falls on the general surface of the land is hopeless, and that that which is collected on snow in inhabited countries containing foundries and the like is doubtful.

But a considerable advance of this question has recently been made in studying the deep-sea deposits collected by the *Challenger* Expedition. Messrs. Murray and Renard,[1] in giving the results of their researches, point out that at the greatest depths of the ocean furthest from land, the sea bottom is very different from that nearer the coast lines.

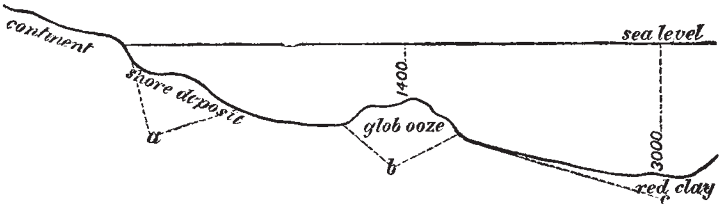

FIG. 3.—Section of ocean showing red clays at depths of 3000 fathoms (18,000 feet).

Under these necessary conditions of exceeding slow deposition and absence from ordinary sources of contamination, it is clear that the problem can be attacked under the best conditions.

We read:—"The considerable distance from land at which we find cosmic particles in greatest abundance in deep-sea deposits, eliminates at once objections which might be raised with respect to metallic particles found in the neighbourhood of inhabited countries. On the other hand, the form and character of the spherules of extra-terrestrial origin are essentially different from those collected near manufacturing centres. These magnetic spherules have never elongated necks or a cracked surface, like those derived from furnaces, with which we have carefully compared them. Neither are the magnetic spherules with a metallic centre comparable either in their form or structure to those particles of native iron which have been described in the eruptive rocks, especially in the basaltic rocks of the north of Ireland, of Iceland, &c."

Messrs. Murray and Renard then state on what they rely in support of their view that many of the particles thus obtained from great depths are of cosmic origin:—

"If we plunge a magnet into an oceanic deposit, especially a red clay from the central parts of the Pacific, we extract particles, some of which are magnetite from volcanic rocks, and to which vitreous matters are often attached; others again are quite isolated, and differ in most of their properties from the former. The latter are generally round, measuring hardly 0·2 mm., generally they are smaller, their surface is quite covered with a brilliant black coating, having all the properties of magnetic oxide of iron; often there may be noticed upon them cup-like depressions clearly marked. If we break down these spherules in an agate mortar, the brilliant black coating easily falls away, and reveals white or gray metallic malleable nuclei, which may be beaten out by the pestle into thin lamellæ. This metallic centre, when treated with an acidulated solution of sulphate of copper, immediately assumes a coppery coat, thus showing that it consists of native iron. But there are some malleable metallic nuclei extracted from the spherules which do not give this reaction, they do not take the copper coating. Chemical reaction shows that they contain cobalt and nickel; very probably they constitute an alloy of iron and these two metals, such as is often found in meteorites, and whose presence in large quantities hinders the production of the coppery coating on the iron. G. Rose has shown that this coating of black oxide of

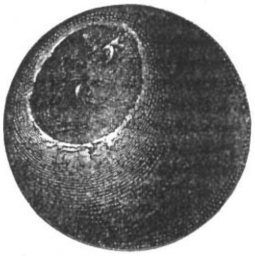

FIG. 4.

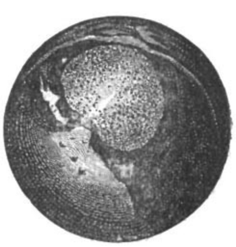

FIG. 5.

FIG. 4.—Black spherule with metallic nucleus (60 : 1). This spherule, covered with a coating of black shining magnetite, represents the most frequent shape. The depression here shown is often found at the surface of these spherules. From 2375 fathoms, South Pacific.

FIG. 5.—Black spherule with metallic nucleus (60 : 1). The black external coating of magnetic oxide has been broken away to show the metallic centre, represented by the clear part at the centre. From 3150 fathoms, Atlantic.

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[1] "Cosmos" (Otté), vol. i. p. 114.

[1] "On the Microscopic Characters of Volcanic Ashes and Cosmic Dust and their Distribution in Deep-sea Deposits," Proc. R.S.E., and NATURE, vol. xxix. p. 585.

iron is found on the periphery of meteorites of native iron, and its presence is readily understood when we admit their cosmic origin. Indeed these meteoric particles of native iron, in their transit through the air, must undergo combustion, and, like small portions of iron from a smith's anvil, be transformed either entirely or at the surface only into magnetic oxide, and in this latter case the nucleus is protected from further oxidation by the coating which thus covers it."

We are next shown that these metallic chondroi occur with stony chondroi, so that if the interpretation of a cosmic origin for the magnetic spherules with a metallic centre be not considered established in a manner absolutely beyond question, it almost becomes so when we take into account their association with the silicate spherules, never found in rocks of a terrestrial origin. These are thus described:—

"Among the fragments attracted by the magnet in deep-sea deposits we distinguish granules slightly larger than the spherules with the shining black coating above described. These are yellowish-brown, with a bronze-like lustre, and under the microscope it is noticed that the surface, instead of being quite smooth, is grooved by thin lamellæ. In size they never exceed a millimetre, generally they are about 0·5 millimetre in diameter; they are never perfect spheres, as in the case of the black spherules with a metallic centre; and sometimes a depression more or less marked is to be observed in the periphery. When examined by the microscope, we observe that the lamellæ which compose them are applied the one against the other, and have a radial eccentric disposition. It is the leafy radial structure (*radialblättrig*), like that of the *chondres* of bronzite, which predominates in our preparations. We have observed much less rarely the serial structure of the *chondres* with olivine, and indeed there is some doubt about the indications of this last type of structure. Fig. 6 shows the characters and texture of one of these spherules magnified twenty-five diameters."

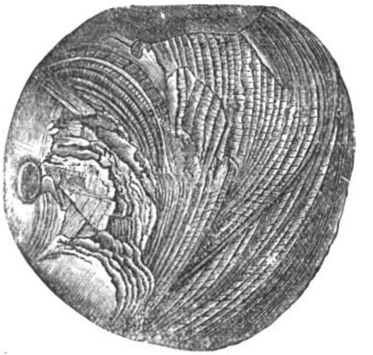

FIG. 6.—Chondros. Spherule of bronzite (25 : 1) from 3500 fathoms in the Central South Pacific, showing many of the peculiarities belonging to *chondres* of bronzite or enstatite.

It is worthy of remark that, associated with these chondroi in the red muds at the greatest depths in the ocean, are found manganese nodules in enormous numbers. If a section be made of one of these, a number of concentric layers will be observed arranged around a central nucleus—the same as in a urinary calculus. When the peroxide of manganese is removed by strong hydrochloric acid, there remains a clayey skeleton which still more strongly resembles a urinary calculus, according to Mr. Murray.

This skeleton contains crystals of olivine, quartz, augite, magnetite, or any other materials which were contained in the clay from which the nodule was taken. In the process of its deposition around a nucleus, the peroxide of manganese has inclosed and incorporated in the nodule the clay and crystals and other materials in which the nucleus was embedded. The clayey skeleton thus varies with the clay or ooze in which it was formed. Those from a fine clay usually adhere well together; those from a globigerina ooze have an areolar appearance; those from a clay with many fine sandy particles usually fall to pieces. Mr. Murray attributes the origin of these nodules entirely to the decomposition of volcanic rocks:—

"Wherever we have pumice containing much magnetite, olivine, augite, or hornblende, and these apparently undergoing decomposition and alteration, or where we have evidence of great showers of volcanic ash, there we find the manganese in greatest abundance. This correspondence between the distribution of the manganese and volcanic *débris* appears to me very significant of the origin of the former. I regard the manganese, as we find it, as one of the secondary products arising from the decomposition of volcanic minerals.

"Manganese is as frequent as iron in lavas, being usually associated with it, though in very much smaller amount. In magnetite and in some varieties of augite and hornblende the protoxide of iron is at times partially replaced by that of manganese.

"In the manganese of these minerals and in the carbonic acid and oxygen of ocean waters we have the requisite conditions for the decomposition of the minerals, the solution of the manganese, and its subsequent deposition as a peroxide."[1]

These nodules have been examined in the same way as the meteoric dust. Naturally the chief manganese fluting (the chief auroral line) has been seen.

The question arises, therefore, whether the origin of these deep-sea concretionary deposits of iron and manganese, which are unrepresented in any deep-sea geological deposit, may not be in part, even if in small part, meteoritic, and represent, like the chondroi, another form of fallen dust.

Proof from Similar Velocities.

Again, the meteorites, as we have seen, enter our atmosphere with very different velocities. The same thing happens with falling stars, which on this account have been divided into three classes as follows:—

Class I. Swift, streak-leaving meteors.
II. Slow, with trains of sparks.
III. Small, quick, short-pathed, sometimes with streaks.

It has also been determined that the luminous effect which is common to the fall of a meteorite or the appearance of a shooting-star begins at about the same height. In fact, we have in meteorites, large fire-balls, and shooting-stars, a progression both with regard to the height at which they become visible and the nearness to the earth at which their luminosity is extinguished.

The actual determination of these heights was commenced by two Göttingen students—Brandes and Benzenberg—in 1798, at the suggestion of Chladni, with the result that the upper reaches of the earth's atmosphere were found to be pierced by bodies entering it with planetary velocities.

Profs. Herschel and Newton were the first to discuss the data accumulated on this subject,[2] while, as early as 1864, Father Secchi made use of the electric telegraph in securing simultaneous observations.[3] The results of these combined inquiries may be thus shown in the case of shooting-stars:—

	Beginning. Height in miles.	End. Height in miles.	Authority.
Europe and America, 1798–1863 ...	70·1 ...	54·2 ...	H.
	73·5 ...	50·6 ...	N.
Italy, 1864	74·6 ...	49·7 ...	S.
Average ...	72·7 ...	51·5	

In Herschel's values fire-balls are excluded, and hence the limits are narrower.[4] Fire-balls often arrive within 20 miles of the earth's surface, and then the concussion is of nearly the same intensity whether stones fall or not.

Such determinations as these, when the observations can be depended upon, can be made with the greatest nicety and by graphical methods. One of the earliest employed—a description of which will give a fair idea of the investigation—is due to Colonel Laussedat.[5]

The observations stating the path of each meteor among the stars having been obtained, a 12-inch celestial globe is "rectified" in the usual manner for the place and time. In this way we get first the azimuth and altitude of the beginning and end of each trail. This is done for each place at which the same meteor is observed.

The results are then plotted on a large-scale map, on which the altitudes and longitudes of the places of observation and the distances between them can be determined. The scale of the map permits the height of the intersection of the lines of sight to be at once found, and the agreement or disagreement of the observations can be noticed, thus allowing the worst observations to be rejected.

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[1] Murray, NATURE, vol. xv. p. 340.

[2] Herschel, B.A. Report, 1863, p. 328; Newton, *Silliman's Journal*, 2nd series, vol xxxvii., July 1864.

[3] *Bull. Meteor.*, vol. iii. p. 67.

[4] *Monthly Notices*, vol. xxv. p. 159.

[5] *Comptes rendus*, vol. lviii. p. 1100, 1864.

By taking such observations as these in different places it is possible not only to determine the height at which they enter but the velocity with which they pass through the upper regions of the air, even supposing they do not eventually get to the bottom. The lowest velocity determined up to the present time is something like 2 miles per second; the maximum is something like 50 miles a second; but we may say that the average rate of movement is 30 miles a second, which is about 150 times faster than a shell leaving one of our most powerful guns.

J. NORMAN LOCKYER.

(*To be continued.*)

THE ELECTRIC TRANSMISSION OF POWER.[1]

II.

THE next point to consider is the loss of power on the road between the dynamo at the one end and the motor at the other. This problem was perhaps seriously attacked for the first time in the discussion of a paper read by Messrs. Higgs and Brittle at the Institution of Civil Engineers in 1878, and that problem was considered in some detail theoretically and experimentally at the lecture I gave during the meeting of the British Association in Sheffield in the following year. It was then shown that, since the power developed by the generator and motor depended on the product of the current into the electric pressure, while the loss when power was transmitted through a given wire depended on the square of the current and was independent of the electric pressure, the economical transmission of power by electricity on a large scale depended on the use of a very large electric pressure and a small current, just as the economic transmission of much power by water depended on the use of a very large water pressure and a small flow of water. At that time it was not thought possible to construct a small dynamo to develop a very large electric pressure, or potential difference as it is technically called, and therefore it was proposed to join up many dynamos in series at the one end and many lamps or electromotors in series at the other, and to transmit the power by a very small current, which passed through all the dynamos and all the lamps in succession, one after the other.

You have an example to-night of the realization of this principle in the fifteen arc lamps that are all in series outside this Drill Hall, and are worked with a small current of only 6·8 amperes, as indicated in the wall diagram; and a further example in the thirty arc lamps at the Bath Flower Show, which are also all worked in series with the small current passing through them; but it is known now how to produce a large potential difference with a single dynamo, so that a single Thomson-Houston dynamo belonging to Messrs. Laing, Wharton, and Down supplies the current for each of the two circuits.

The electric pressure, or potential difference, between the terminals of any arc lamp is not high, but it is between the main wires near the dynamo as well as between these wires and the ground. How far does this lead to the risk of sparks or unpleasant shocks? That is a point that can be looked at in a variety of ways. First, there is the American view of the matter, which consists in pointing out to people exactly what the danger is, if there be any, and training them to look out for themselves: let ordinary railway trains, say the Americans, run through the streets, and let horses learn to respect the warning bell. Next, there is the semi-paternal English system, which cripples all attempts at street mechanical locomotion, because we are conservative in our use of horses, and horses are conservative in their way of looking at horseless tramcars. Lastly, there is the foreign paternal system, which, carried to its limit, would prohibit the eating of dinners because some people have at some time choked themselves, and would render going to bed a penal offence because it is in bed that most people have died.

We laugh a good deal at the rough-and-ready manner adopted on the other side of the Atlantic. The Americans, no doubt, are very ignorant of the difficulties that properly-minded people would meet with, but it is a blissful ignorance where it is folly to be wise. Every English electrician who has travelled in America comes back fully impressed with their enterprise and their happy-go-lucky success. They have twenty-two electric tramways, carrying some 4,000,000 passengers annually, to our four electric tramways at Portrush, Blackpool, Brighton, and Bessbrook. Why, New York city alone, Mr. Rechenzaun tells me, possesses 300 miles of ordinary tramway track, and Philadelphia 430 miles, so there is more tramway line in these two cities than in the whole of the United Kingdom put together. Now there would be no difficulty in proving, to anyone unfamiliar with railway travelling, that to go at 50 miles an hour round a curve with only a bit of iron between him and eternity would be far too risky to be even contemplated. And yet we do go in express trains, and even 80 miles an hour is beginning to be considered not to put too great a demand on the funds of life insurance companies. The American plan of basing a conclusion on experience rather than on anticipations is not a bad one; and if we follow that plan, then, taking into account that there are 75,000 arc lights alight every night on the Thomson-Houston high-potential circuits throughout the world, and the comparatively small number of people that have suffered in consequence (not a single person, I am assured, outside the companies' staffs) we are compelled to conclude that high potential now is what 30 miles an hour was half a century ago—uncanny rather than dangerous.

But it is possible to use a very large potential difference between the main wires by means of which the electric power is economically conveyed a considerable distance, and transformed into a very small potential difference in the houses where it is utilized. An electric transformer is equivalent to a lever, or wheel and axle, or any other of the so-called mechanical powers. You know that a large weight moving through a small distance can raise a small weight through a large distance; there is no gain in the amount of work, but only a transformation of the way in which the work is done. A large weight moving through a small distance is analogous with a high potential difference and a small current, while a small weight moving through a large distance is analogous with a small potential difference, and a large current, and an electric transformer is for the purpose of effecting the transformation with as little loss as possible, so that what is lost in potential difference may, as far as possible, be all gained in current.

Electrical transformation may be effected by (1) alternate current transformers, (2) motor-dynamos, (3) accumulators, or secondary batteries, (4) direct-current transformers. Of these apparatus, the eldest by far is the alternate-current transformer, as it is merely the development of the classical apparatus invented by Faraday in 1831, and familiar to many of you as the Ruhmkorff, or induction-coil. A combination of a motor and dynamo was suggested by Gramme in 1874. Accumulators are the outcome of Planté's work, while direct-current transformers are quite modern, and not yet out of the experimental stage.

After studying the literature on this subject, it appears, as far as I have been able to judge, that the first definite proposal to use a high potential difference in the street mains, and transform down to a low potential difference in the houses, was made in the lecture given by me at the meeting of the British Association in Sheffield in 1879, on which occasion I explained and showed in action the motor-dynamo principle suggested by Prof. Perry and myself. The apparatus on the platform is not unlike that shown on the former occasion: an Immisch motor working at 500 volts, and with a current of 6·8 amperes, is geared direct to a Victoria Brush dynamo giving five times that current, and we will now use this larger current to produce an electric fire. [Experiment shown.] Messrs. Paris and Scott have combined the motor and dynamo into one machine, which they have kindly lent me, and by means of which we are now transforming about 700 volts and 6·8 amperes into 100 volts and about 40 amperes used to light that group of sunbeam incandescent lamps or work these motors. [Experiment shown.]

Lastly, here is a working illustration of the double transformation proposed by MM. Deprez and Carpentier in 1881, by means of which—while the potential difference between the mains may be 2000 or 10,000 volts, if you like—not merely is the potential difference in the house so low that you could hardly feel anything if you touched the wires, but, in addition, there is the same security against shocks in the dynamo-room. This alternate-current machine is producing about 50 volts, which is transformed up to 2000 volts by means of this transformer. At the other end of the platform, by means of a similar transformer, the 2000 volts is transformed down again to 50 volts, employed to light that cluster of low-voltage incandescent lamps. [Experiment shown.] For the use of this apparatus I am indebted to the kindness of the Anglo-American Brush Company.

In this experiment there is, as a matter of fact, still more transformation than that I have yet mentioned, because, whereas in actual practice the alternate-current dynamo, as well as the small dynamo used to produce the current for magnetizing the electromagnets in the alternate-current dynamo, would be worked by

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[1] Lecture delivered by Prof. Ayrton, F.R.S., at the Drill Hall, Bath, on Friday, September 7, 1888. Continued from p. 511.